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NATIONAL DAM SAFETY PROGRAM. WILLOW CREST DAM (NJ-00272), DELAW--ETC(U)

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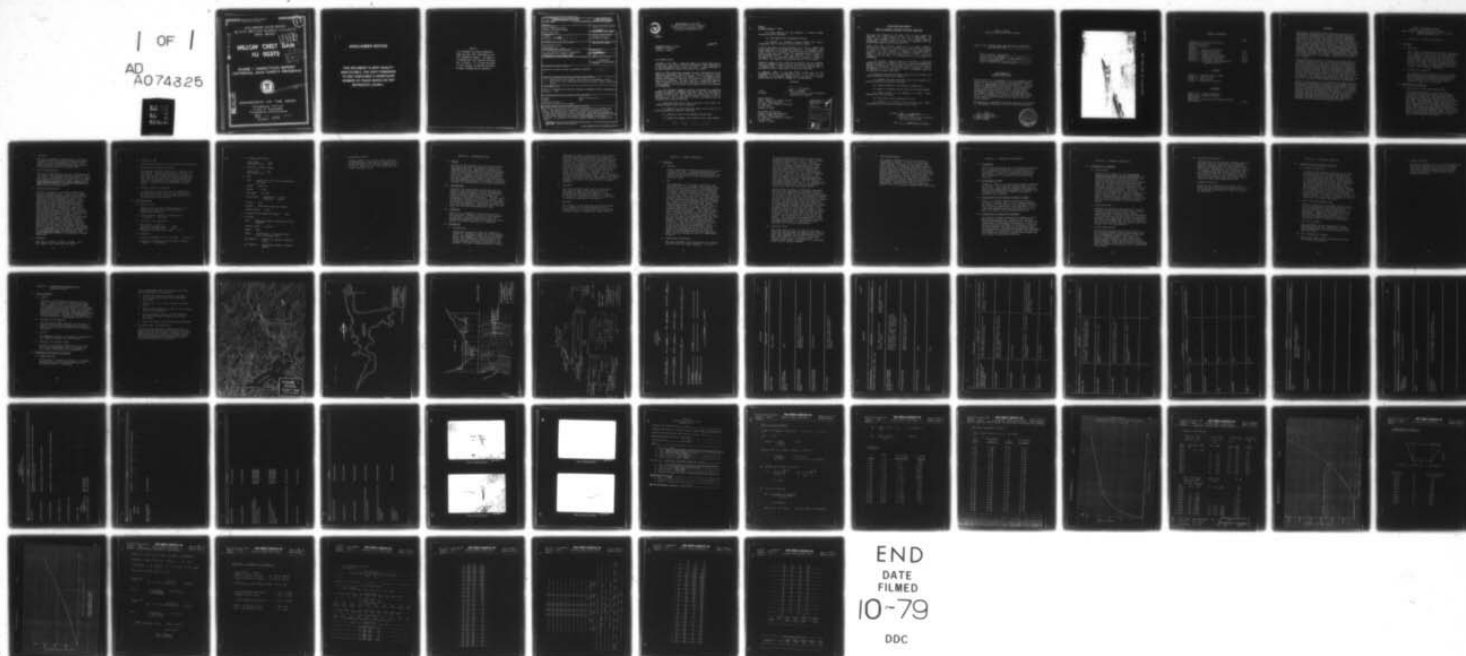
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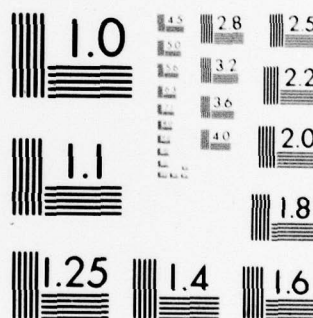
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PHASE 1 INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM



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DEPARTMENT OF THE ARMY

Philadelphia District  
Corps of Engineers  
Philadelphia, Pennsylvania

79 09 24 046  
August, 1979

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| 1. REPORT NUMBER<br>NI00272  | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER                                  |
| 4. TITLE (and Subtitle)<br>Phase I Inspection Report<br>National Dam Safety Program<br>Willow Crest Dam<br>Sussex County, N.J.   |                       | 5. TYPE OF REPORT & PERIOD COVERED<br>(9) FINAL rept.          |
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| 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)<br>(6) National Dam Safety Program. Willow Crest Dam (NJ-00272), Delaware River Basin, Black Brook, Sussex County, New Jersey. Phase 1 Inspection Report.   |                       |  |
| 18. SUPPLEMENTARY NOTES<br>Copies are obtainable from National Technical Information Service, Springfield, Virginia, 22151.  |                       |  |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number)<br>Seepage Willow Crest Dam, N.J.<br>Joints Dams<br>Structural Analysis<br>National Dam Inspection Act Report   |                       |  |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report. |                       |  |



DEPARTMENT OF THE ARMY  
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS  
CUSTOM HOUSE-2 D & CHESTNUT STREETS  
PHILADELPHIA, PENNSYLVANIA 19106

IN REPLY REFER TO

NAPEN-D

17 SEP 1979

Honorable Brendan T. Byrne  
Governor of New Jersey  
Trenton, NJ 08621

Dear Governor Byrne:

Inclosed is the Phase I Inspection Report for Willow Crest Dam in Sussex County, New Jersey which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given in the front of the report.

Based on visual inspection, available records, calculations and past operational performance, Willow Crest Dam, initially listed as a high hazard potential structure, but reduced to a significantly hazard potential structure as a result of this inspection, is judged to be in good overall condition. The dam's spillway is considered inadequate since 51 percent of the 100 year flood would overtop the dam. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy should be determined by a qualified professional consultant engaged by the owner using more sophisticated methods, procedures, and studies within six months from the date of approval of this report. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1980.

b. Within one year from the date of approval of this report, the following remedial actions should be completed:

(1) Regrade the eroded downstream slopes and the sides of the auxiliary channel and reseed the bare areas.

(2) Reseal the joints in the concrete spillway crest.

(3) Monitor the seepage in the vicinity of the right abutment.

79 09 24 046



NAPEN-D

Honorable Brendan T. Byrne

(4) Place barriers at the abutments to inhibit illegal vehicular use of the dam crest.

(5) Clear debris from the downstream channel.

(6) Establish an inspection program whereby any further deterioration can be noted and corrective measures taken.

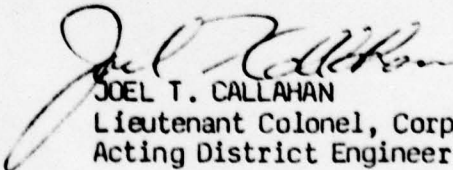
A copy of the report is being furnished to Mr. Dirk C. Hofman, New Jersey Department of Environmental Protection, the designated State Office contact for this program. Within five days of the date of this letter, a copy will also be sent to Congressman James A. Courter of the Thirteenth District. Under the provision of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, five days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

An important aspect of the Dam Safety Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely,

1 Incl  
As stated

  
JOEL T. CALLAHAN  
Lieutenant Colonel, Corps of Engineers  
Acting District Engineer

Copies furnished:  
Dirk C. Hofman, P.E., Deputy Director  
Division of Water Resources  
N.J. Dept. of Environmental Protection  
P.O. Box CNO29  
Trenton, NJ 08625

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WILLOW CREST DAM (NJ00272)

CORPS OF ENGINEERS ASSESSMENT OF GENERAL CONDITIONS


This dam was inspected on 30 April 1979 by Louis Berger and Associates, Inc. under contract to the State of New Jersey. The State, under agreement with the U.S. Army Engineer District, Philadelphia, had this inspection performed in accordance with the National Dam Inspection Act, Public Law 92-367.

Willow Crest Dam, initially listed as a high hazard potential structure, but reduced to a significantly hazard potential structure as a result of this inspection, is judged to be in good overall condition. The dam's spillway is considered inadequate since 51 percent of the 100 year flood would overtop the dam. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy should be determined by a qualified professional consultant engaged by the owner using more sophisticated methods, procedures, and studies within six months from the date of approval of this report. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1980.

b. Within one year from the date of approval of this report, the following remedial actions should be completed:

- (1) Regrade the eroded downstream slopes and the sides of the auxiliary channel and reseed the bare areas.
- (2) Reseal the joints in the concrete spillway crest.
- (3) Monitor the seepage in the vicinity of the right abutment.
- (4) Place barriers at the abutments to inhibit illegal vehicular use of the dam crest.
- (5) Clear debris from the downstream channel.
- (6) Establish an inspection program whereby any further deterioration can be noted and corrective measures taken.

APPROVED: 

JOEL T. CALLAHAN

Lieutenant Colonel Corps of Engineers  
Acting District Engineer

DATE: 13 September 1979



PHASE I REPORT  
NATIONAL DAM INSPECTION PROGRAM

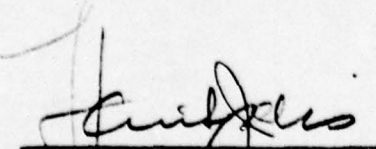
Name of Dam Willow Crest Dam Fed ID# NJ 00272 and  
NJ ID# 567 & 572

State Located New Jersey  
County Located Sussex  
Coordinates Lat. 4106.1 - Long. 7450.6  
Stream Black Brook  
Date of Inspection 30 April 1979

ASSESSMENT OF  
GENERAL CONDITIONS

Willow Crest Dam is assessed to be in an overall good condition and is recommended to be downgraded from a high to a significant hazard classification. Failure would not appreciably increase the danger of loss of life or downstream property damage. No detrimental findings were uncovered to warrant further study. Recommended remedial measures to be undertaken in the future include repairing the sloughed embankment areas at the abutments, resealing the concrete joints in the apron slab and removing the debris from the outlet channel.

The dam has an inadequate spillway capacity, being able to accommodate only 50% of the 100-year design flood.

  
\_\_\_\_\_  
F. Keith Jolls P.E.  
Project Manager





OVERVIEW OF WILLOW CREST DAM

MAY, 1979

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## PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

PHASE I INSPECTION REPORT  
NATIONAL DAM INSPECTION PROGRAM  
NAME OF DAM: WILLOW CREST DAM FED ID# NJ 00272  
AND NJ ID #567 & 572

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority

This report is authorized by the Dam Inspection Act, Public Law 92-367, and has been prepared in accordance with Contract FPM-36 between Louis Berger & Associates, Inc. and the State of New Jersey and its Department of Environmental Protection, Division of Water Resources. The State, in turn, is under agreement with the U.S. Army Corps of Engineers, Philadelphia to have this inspection performed.

b. Purpose of Inspection

The purpose of this inspection is to evaluate the structural and hydraulic condition of the Willow Crest Dam and appurtenant structures, and to determine if the dam constitutes a hazard to human life or property.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances

The Willow Crest Dam is a 400-foot long, 17-foot high earth embankment with an impervious clay cutoff key. The upstream face is protected by riprap to elevation 766.9 as are the sides and downstream channel of the auxiliary spillway. The principal outlet consists of a 96" corrugated metal pipe drop inlet with a low level drain and a 72 inch diameter discharge pipe. The trapezoidal auxiliary spillway, which is cut into the left abutment zone, is 80 feet wide with a negative approach slope, an 20' x 80' level concrete apron and a positively sloped, riprap protected outlet channel.



b. Location

The dam is located on Black Brook, a tributary to Paulins Kill in Stillwater Township, Sussex County. It is approximately one and a half miles northwest of Swartswood Lake and one and six-tenths miles south of Crandon Lake.

c. Size Classification

The dam at Willow Crest Lake has a maximum height of 17 feet and a maximum storage capacity of 351 acre-feet. Accordingly, this dam is in the small size category as defined by the criteria in the Recommended Guidelines for Safety Inspection of Dams (storage capacity less than 1,000 acre-feet and height less than 40 feet).

d. Hazard Classification

The dam is located in a heavily wooded rural portion of Sussex County. There is a lightly travelled local road and several homes located 1200 to 1500 feet downstream. Due to the narrowness of the discharge channel, a small downstream bridge could sustain some flood damage if the dam collapsed but the homes, being some distance upslope from the stream bed, would be less susceptible. About 1.6 miles downstream, the channel passes through Swartswood (a community of some 30 to 40 homes) before entering Swartswood Lake. The lake and its adjoining marshlike environment has a surface area of about one square mile and would have sufficient storage capacity to absorb a dam failure from Willow Crest Lake without significant impact to the adjacent dwellings. However, because appreciable damage could be sustained at two county road bridges and several homes on the banks of the channel in Swartswood, it is recommended that this dam be downgraded to the significant hazard classification, even though these are located a considerable distance downstream.

e. Ownership

This dam is owned by Thomas S. Brush, 179 E. 70th Street, New York, New York 10021.

f. Purpose of Dam

The purpose of the dam is primarily for recreation.

g. Design and construction History

The dam was originally designed in 1964 by Snook and Hardin, Consulting Engineers, of Newton, New Jersey. For an unknown reason, the spillway was redesigned by Charles W. Boesch of Hacketts-town, New Jersey and a permit for construction issued in May 1964 by the Department of Conservation. Construction was completed in August 1965.

h. Normal Operating Procedures

At the present time there are no operational procedures in effect and with the exception of the dam itself, the site is completely devoid of habitation or development.

1.3 PERTINENT DATA

a. Drainage Area

Willow Crest Dam has a drainage area of 7.45 square miles which consists primarily of undeveloped woodlands.

b. Total spillway capacity at maximum pool elevation - 5113 cfs

c. Elevations (ft. above MSL)

Top of dam - 767.9  
Principal spillway crest - 762.9  
Auxiliary spillway crest - 764.3  
Streambed at centerline of dam - 751+

d. Reservoir

Length of maximum pool (top of dam) - 2,850 feet

Length of recreation pool (principal spillway crest) - 2,700 feet

e. Storage (acre-feet)

Top of dam - 351  
Recreation pool - 168

f. Reservoir Surface (acres)

Top of dam - 45  
Recreation pool - 28

g. Dam

Type - Earth with drop inlet and auxiliary  
spillway

Length - 400 feet

Height - 17 feet

Top Width - 20 feet

Side Slopes - Downstream - 2.5H:1V  
Upstream - 3H:1V

Zoning - None

Cutoff - Impervious clay key section.

Grout curtain - None

h. Diversion and Regulating Tunnel - None

i. Spillway

Type - Auxiliary channel excavated at left  
abutment

Channel width - 80 feet

Gates - None

Crest - 20 feet long, 8" concrete slab  
with 5 foot deep sill

U/S Channel - Negatively sloped, vegetated  
inlet

D/S Channel - Positively sloped, riprapped  
outlet



j. Regulating Outlets

Primary outlet is a 2 stage, drop inlet with a corrugated metal riser and 72" outlet pipe. Crest elevation of the 96-inch diameter riser is 762.9. There is a 24" low level drain at invert elevation 751.6.

## SECTION 2 - ENGINEERING DATA

### 2.1 DESIGN

Details of the original and revised 1964 design were available from the Bureau of Flood Plain Management records. Additional hydrologic and hydraulic data was obtained from the Dam Application, review report, and correspondence between the State's reviewing engineer and the designer. The design conforms with current accepted engineering standards and a design storm of 50-years was employed and approved by the State's reviewing engineer for establishing the spillway capacities.

### 2.2 CONSTRUCTION

Copies of the Construction Specifications were available and construction of the dam and appurtenant structures appears to have followed the design and specifications quite closely (as verified in the field inspection). However, field measurements indicate the width of the dam crest is closer to 20 feet rather than 16 feet as shown on the design drawings. There does not appear to have been any changes or modifications to the dam since the original construction in 1965.

### 2.3 OPERATION

There is no information available pertaining to dam operation. However, since the sole purpose of the dam is the impoundment of a lake for recreational purposes, the self-regulating outlet appears to function adequately as designed.

### 2.4 EVALUATION

#### a. Availability

Sufficient engineering data was obtained to assess the structural stability of the embankment. The foundation stability was evaluated within the framework of data provided on the plans, the construction specifications, and in geotechnical references pertaining to the damsite. The dam is located across a thalweg



underlain by recent alluvium and a thick mantle of ground moraine deposited by the Wisconsin glacier. The stratified sand and gravel alluvium represents a reworking of the underlying glacial till by the original water course. The till is a heterogenic mixture of unconsolidated, unstratified soil fractions which range in size from clay particles to boulders, with a predominance of silt. The overburden is generally 5 to 10 feet thick in this area and is underlain by the Ordovician-age Martinsburg shale. This formation is quite thick with bedding that varies considerably from the horizontal and has weathered on its upper surface to a gray silty clay layer of variable thickness.

b. Adequacy

The field inspection and review of the available design plans reveal that the dam is structurally sound and well-built. It is believed that the data available is adequate to render this assessment without the necessity of gathering additional information.

c. Validity

The validity of the available engineering data as it pertains to design concepts and the construction is not challenged and is accepted without recourse to additional investigations.

## SECTION 3 - VISUAL INSPECTION

### 3.1 FINDINGS

#### a. General

Visual inspection of Willow Crest Dam took place on April 30, 1979. Although maintenance has apparently been neglected for several years, the overall condition of the dam and facilities was generally good.

#### b. Dam

The embankment is a straight, relatively low structure lying in a narrow, steep sided valley. The dam crest exhibits signs of occasional use by vehicles but apparently at very infrequent intervals. While the grass cover on the crest is relatively short, the front and back slopes are overgrown with brush which, on the foreslope, conceals most of the riprap. The alignment of the embankment appears satisfactory although the junction of the embankment and right abutment (near a private service road) appears somewhat depressed and is soft in the vicinity of the abutment due to surface runoff and a probable high water table. Light erosion was noted behind the headwall of the outlet conduit and at several locations on the front slope. Some riprap has been displaced toward the lake at the left end of the embankment but the slope appears straight and stable indicating the movement of the stone was possibly caused by vandalism. Some water was noted near the toe at the right side of the embankment but it could not be determined whether the source is a drainage diversion ditch as shown on the plans, high groundwater emanating from the junction of the embankment and the right abutment, seepage through the dam or a combination thereof.

#### c. Appurtenant Structures

The main spillway riser and outfall are located 132 feet from the right abutment. A 9' x 9',

10 gage corrugated metal cover plate is supported by and welded to four 2' high, 10 gage, diagonally placed, anti-vortex, vertical splitter plates. These in turn, are welded to the 96" diameter corrugated metal riser. With the exception of small floating debris and some rust on the splitter plates, the riser assembly appears to be in satisfactory condition. However, the gate wheel is missing from the stem of the low level drain. The outlet headwell is in satisfactory condition with only minor spalling, efflorescence and a few small surface cracks. The 72" diameter corrugated outlet pipe also is in a satisfactory condition although the interior bituminous coating has worn off the paved invert.

The auxiliary spillway is overgrown with thick brush on both upstream and downstream slopes. The concrete slabs at the crest are cracked and heaved due to frost action. Differential movement of one half to two and one-half inches was noted and grass and weeds are growing through the mastic joints. The back slope beyond the auxiliary spillway, which cuts deep into the valley side has sloughed off towards the spillway but appears to have reached a stable configuration. The sloughing begins at a spring line some 20 feet higher than the spillway crest. Erosion gullies were also noted on this slope and the presence of water in the spillway along the toe of the slumped area confirmed that a high water table exists. The riprapped area downstream of the auxiliary spillway is in satisfactory condition although heavy brush is also beginning to encroach into the slope protection.

d. Reservoir Area

The water depth in the vicinity of the riser tower and the upstream toe appears quite shallow which may indicate heavy sedimentation near the dam. The shoreline of the lake is devoid of habitation and is in a pristine state. The natural slopes range from moderate to relatively steep and are heavily wooded.



e. Downstream Channel

The channel immediately below the outlet is protected by riprap. A large tree and other timber debris has fallen in the channel just below the dam. The downstream channel follows the narrow valley for about 1200 feet until it passes under Old Tannery Road where the existing culvert appears to severely constrict the stream during heavy flows. Below Old Tannery Road, the channel narrows and steepens until it passes under County Road 521 in Swartswood and enters Swartswood Lake. Several homes are located near the stream at Old Tannery Road as well as in Swartswood. However, most of the residences appear to be at or above a maximum flood elevation.

## SECTION 4 - OPERATIONAL PROCEDURES

### 4.1 PROCEDURES

Willow Crest Dam functions as a retaining structure for a recreational lake and was designed to be self-regulating (requiring no manual operational procedures). There is a gated low level drain but, according to the owner, this has never been utilized.

### 4.2 MAINTENANCE OF DAM

Presently, there is no formal maintenance performed on the dam. The brush and sapling growth on the auxiliary spillway channel indicate that there has been little maintenance performed for several years although the grass on the crest of the dam is presently well cropped.

### 4.3 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

There is no formal warning system in effect at this dam. Further, due to the isolated location and absence of residents in the immediate vicinity, it is unlikely that anyone would be aware of an impending hazard condition or failure at the dam until the effects were observed downstream.

### 4.4 EVALUATION OF OPERATIONAL ADEQUACY

As designed, formal regulatory procedures at this dam appear superfluous. However, the complete lack of maintenance and monitoring of the physical conditions are considered deficiencies. While the design inherently provides a considerable measure of flood control and requires no attendant operational personnel, periodic maintenance and inspection are deemed to be essential to assure continued safe performance as well as to provide some forewarning of a potential hazardous condition.



## SECTION 5 - HYDRAULIC/HYDROLOGIC

### 5.1 EVALUATION OF FEATURES

#### a. Design Data

Based on the criteria in the Recommended Guidelines for Safety Inspection of Dams, the 100-year frequency event was selected as the design storm by the inspecting engineer. Precipitation data was obtained from Technical Paper 40 and NOAA Technical Memorandum NWS Hydro 35. Inflow to the reservoir for the selected 100-year storm was computed utilizing the HEC-1 computer program. This gave a peak inflow into the reservoir of 10,620 cfs. Routing this through the reservoir reduced the peak to 10,279 cfs. The combined spillways have a maximum discharge capacity of approximately 5,113 cfs before overtopping occurs and can therefore accommodate 50% of the design flood.

#### b. Experience Data

The dam was originally designed for a 50-year frequency storm using the mean of the Central Jersey and North Jersey Run-off Curves. Employing these, the peak inflow was determined to be 1966 cfs and the drop inlet and auxiliary spillway were accordingly sized to accommodate the design discharge with 1.5 feet of freeboard. There are no records that the dam has been overtopped since its construction.

#### c. Visual Observations

At the time of inspection the water level in the lake was about 3 inches above normal stage with a discharge of approximately 10 cfs in the 72" diameter outfall. The outlet was flowing freely despite a large toppled tree which creates a minor obstruction in the downstream channel. There are no visible indications that the auxiliary spillway has ever transmitted storm flows.

d. Overtopping Potential

Although there is no physical evidence that the dam has ever been overtopped, the appended analysis indicates that the dam would be overtopped by approximately two feet for the 100 year flood. Accordingly, the discharge capacity is inadequate but dam failure resulting from overtopping would not significantly increase the hazard to loss of life downstream from the condition that would exist just before overtopping failure (see paragraph 1.2.d).

e. Drawdown Potential

Using the 24" Ø sluice gate opening at the bottom of the riser tower (at invert El. 751.6), it would take approximately 3 days to dewater the reservoir.

## SECTION 6 - STRUCTURAL STABILITY

### 6.1 EVALUATION OF STRUCTURAL STABILITY

#### a. Visual Observations

In view of the relative young age of the dam embankment and the well-designed and supervised construction, the dam is deemed to be in a good overall condition. The upper zones of the riprap protection show little evidence of subgrade subsidence and the main embankment crest and adjoining cut slopes along the auxiliary spillway are at true design grade and are marred only by minor vehicular rutting. The inspection team noted some apparent seepage at the downstream toe but this was deemed to be of a minor importance in view of the hazard classification. In summary, nothing was visually noted to create or worsen a hazardous condition that cannot be readily corrected.

#### b. Design and Construction Data

From the review of the contract plans for the initial construction, the design appears to be well-engineered, reflects a conservative approach and employs conventional analytical techniques. Based upon the condition of the dam and the hazard classification, it is believed that additional design studies are unnecessary under the purview of PL 92-367.

#### c. Operating Records

The performance of this structure has been satisfactory since its completion, although normal maintenance and repairs appear to have been neglected.

#### d. Post Construction Changes

There have been no major modifications since the initial construction.



e. Seismic Stability

The dam is located in Zone 1 and has negligible potential vulnerability to seismic loadings. Experience indicates that dams in this zone will have adequate stability under dynamic loading conditions if stable under static loading conditions.

## SECTION 7 - ASSESSMENTS/RECOMMENDATIONS/ REMEDIAL ACTIONS

### 7.1 DAM ASSESSMENT

#### a. Safety

Subject to the inherent limitations of the Phase I visual inspection, Willow Crest Lake Dam is judged to be in a good overall condition although the spillway capacity is incapable of transmitting the design flood. No seriously detrimental conditions were observed and overtopping would not seriously exacerbate downstream safety conditions. The dam is recommended to be reclassified in a significant hazard category.

#### b. Adequacy of Information

The information made available by the owner is deemed to be adequate regarding the analyses and evaluation of safe operation and structural stability.

#### c. Urgency

No immediate urgency is attached to implementing the remedial measures set forth below.

#### d. Necessity for Further Study

In view of the overall condition of this dam, additional inspections under the purview of P.L. 92-367 are deemed to be unnecessary.

### 7.2 RECOMMENDATIONS/REMEDIAL MEASURES

#### a. Recommendations

On the basis of present conditions, no remedial improvements are envisioned insofar as the spillway capacity is concerned.

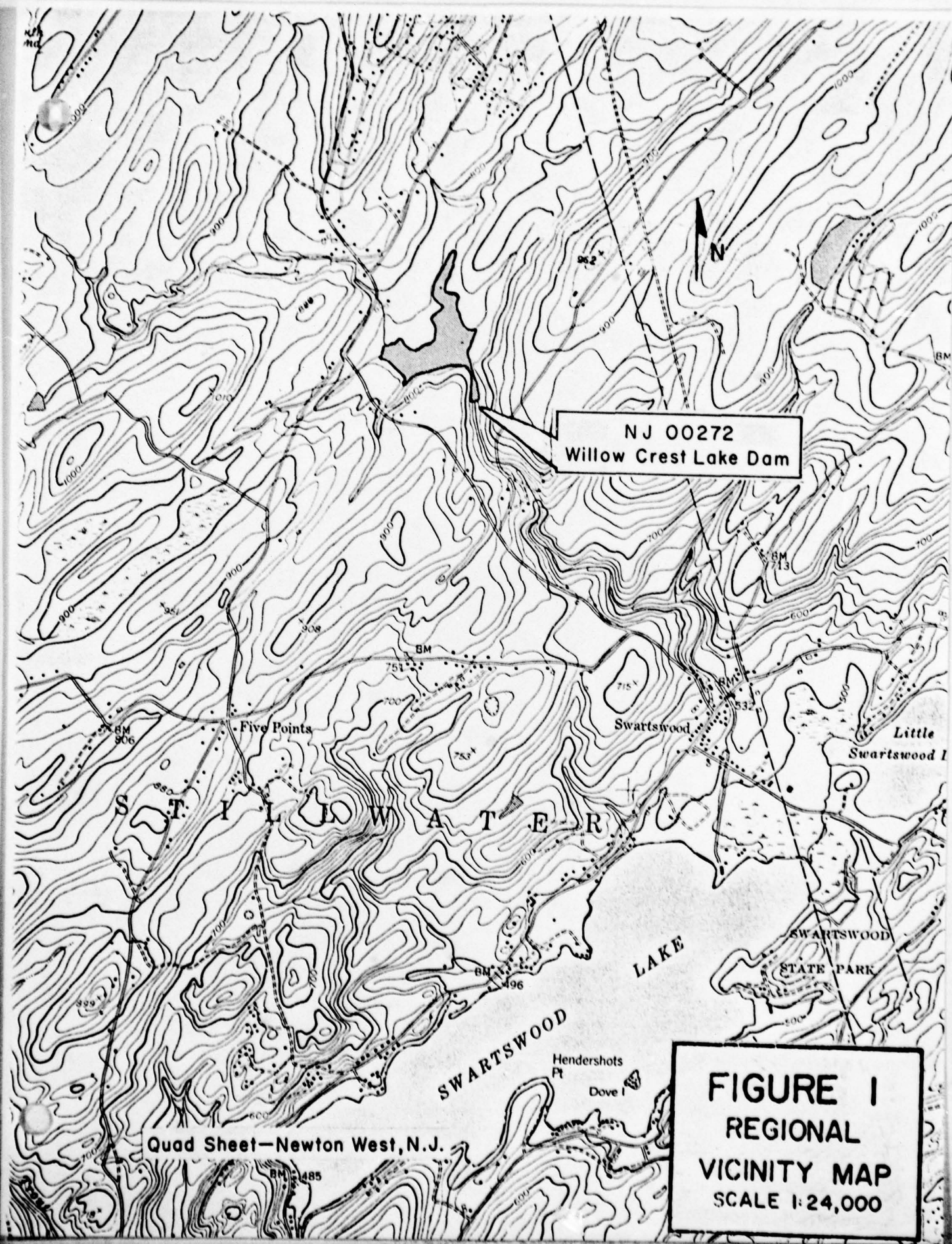
It is recommended that the following be taken under advisement in the future:

- Regrade the eroded backslopes and sides of the auxiliary channel and reseed the bare areas.
- Reseal the joints in the concrete spillway crest.
- Monitor the backslope seepage in the vicinity of the right abutment.
- Place vehicular barriers at the abutments to inhibit illegal vehicular use of the dam crest.
- Clear the debris from the downstream channel.

b. O&M Maintenance and Procedures

In view of the assessment contained herein, no additional procedures other than normal maintenance appear to be required. However, the owner should establish an inspection program whereby any further deterioration could be noted and corrective measures be undertaken.

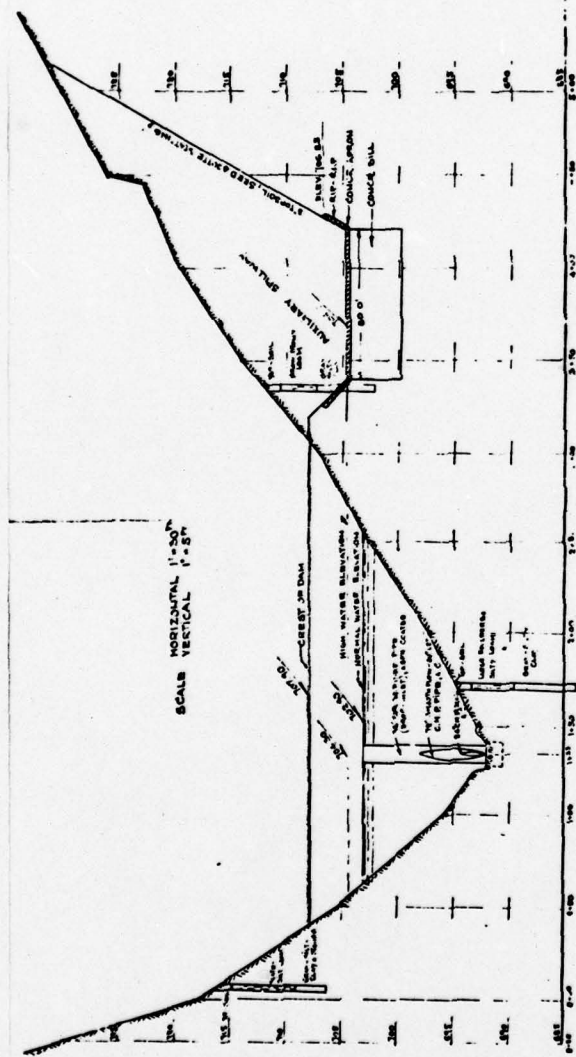




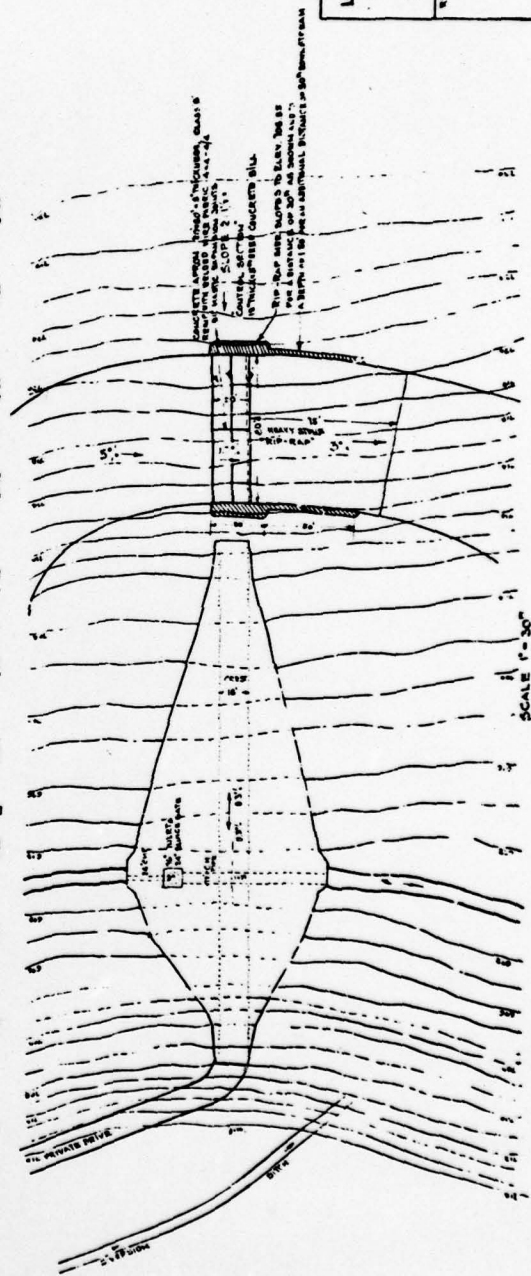
**FIGURE 1**  
**REGIONAL**  
**VICINITY MAP**  
**SCALE 1:24,000**







*Datum +60 = MSL*



LONGITUDINAL SECTION & TOP VIEW

OF PROPOSED

WILLOW CREST DAM

STILL WATER TWP. SUGAR CO. M.D.

REVISION DEC. 1964 SCALE AS SHOWN

OCTOBER, 1964

CHAS. W. BROWN, INC. - ENGINEERS & ARCHITECTS

105 E. C. HACKETT ST. M.D.

LICENSE NO. 1113

FIG. 3





| Name | Dam | Willow Crest | County | Sussex | State | New Jersey | Coordinators | NJDEP |
|------|-----|--------------|--------|--------|-------|------------|--------------|-------|
|------|-----|--------------|--------|--------|-------|------------|--------------|-------|

| Date(s) | Inspection | Weather | Temperature |
|---------|------------|---------|-------------|
| 4/30/79 |            | Clear   | 75°         |

| Pool Elevation at Time of Inspection | 763 | M.S.L. | Tailwater at Time of Inspection | 753 | M.S.L. |
|--------------------------------------|-----|--------|---------------------------------|-----|--------|
|                                      |     |        |                                 |     |        |

**Inspection Personnel:**

**T. Chapter** **K. Jolls**

K. Greenberg

**M. Carter**

**T. Chapter** **Recorder**

# EMBANKMENT

| VISUAL EXAMINATION OF  | OBSERVATIONS   | REMARKS OR RECOMMENDATIONS |
|--|--|----------------------------|
| SURFACE CRACKS   | None visible   |                            |
| UNUSUAL MOVEMENT OR<br>CRACKING AT OR BEYOND<br>THE TOE      | None   |                            |
| SLOUGHING OR EROSION OF<br>EMBANKMENT AND ABUTMENT<br>SLOPES | Sloughing of hillside on left<br>abutment where aux. spillway cut<br>into slope. |                            |
| VERTICAL AND HORIZONTAL<br>ALIGNMENT OF THE CREST            | Satisfactory   |                            |
| RIPRAP FAILURES  | None noted. Some displaced at<br>left end probably caused by<br>vandals.         |                            |



EMBANKMENT

REMARKS OR RECOMMENDATIONS

OBSERVATIONS

VISUAL EXAMINATION OF

EXCESSIVE SHRUB GROWTH, TREES, ETC.

Yes - small trees, brush  
on both slopes.

Growth should eventually  
be removed.

JUNCTION OF EMBANKMENT  
AND ABUTMENT, SPILLWAY  
AND DAM

Right abutment slope damp due to  
ground water. Left abutment wet  
due to ground water. Pooled water  
at left edge of aux. spillway.

ANY NOTICEABLE SEEPAGE

Seepage along right toe from abut-  
ment drainage diversion ditch.

STAFF GAGE AND RECORDER

None

DRAINS

None

OUTLET WORKS

| VISUAL EXAMINATION OF  | OBSERVATIONS   | REMARKS OR RECOMMENDATIONS   |
|--|--|--|
| CRACKING AND SPALLING OF<br>CONCRETE SURFACES IN<br>OUTLET CONDUIT | One slight surface crack in head wall.<br>Very light spalling on edges.                            | Concrete in generally good<br>condition.                                 |
| INTAKE STRUCTURE   | Drop inlet satisfactory, some debris/<br>wood. Gate wheel missing from stem of<br>low level drain. |  |
| OUTLET STRUCTURE   | Satisfactory   |  |
| OUTLET CHANNEL   | Narrow natural channel. Big tree down<br>in channel.   | Slight erosion to left of<br>head wall. Riprap on banks<br>near outfall. |
| EMERGENCY GATE   | Not observed.  |  |

# UNGATED AUXILIARY SPILLWAY

| VISUAL EXAMINATION OF | OBSERVATIONS  | REMARKS OR RECOMMENDATIONS |
|-----------------------|---|----------------------------|
| CONCRETE WEIR         | 25'x80' concrete slab has cracks up to ½ inch wide. Differential settlement of 2.5" noted. Weeds in expansion joints. |                            |
| APPROACH CHANNEL      | Overgrown with 6' high brush. Neg. slope.   |                            |
| DISCHARGE CHANNEL     | Riprap extends 80' down channel. Overgrown beyond riprap. Positive slope  |                            |
| BRIDGE AND PIERS      | None in immediate vicinity. Bridge downstream.  |                            |



# INSTRUMENTATION

| VISUAL EXAMINATION<br>MONUMENTATION/SURVEYS | None | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|------|--------------|----------------------------|
|   |      |              |                            |
| OBSERVATION WELLS                           | None |              |                            |
| WEIRS                                       | None |              |                            |
| PIEZOMETERS                                 | None |              |                            |
| OTHER                                       | None |              |                            |

RESERVOIR

VISUAL EXAMINATION OF

OBSERVATIONS

REMARKS OR RECOMMENDATIONS

SLOPES

3H:1V heavily wooded slopes. No  
homes on lake or immediately  
downstream.

SEDIMENTATION

None noted

DOWNSTREAM CHANNEL

REMARKS OR RECOMMENDATIONS

OBSERVATIONS

VISUAL EXAMINATION OF

CONDITION  
(CONSTRUCTIONS,  
DEBRIS, ETC.)

Natural debris, trees etc.

SLOPES

Steep sided

One at bridge about 1200' downstream  
Several homes 8600' downstream in Swartswood

APPROXIMATE NO.  
OF HOMES AND  
POPULATION



CHECK LIST  
ENGINEERING DATA  
DESIGN, CONSTRUCTION, OPERATION

| ITEM                       | REMARKS  |
|----------------------------|--|
| PLAN OF DAM                | Available in files of NJDEP, Bureau of Flood Plain Management<br>Prospect St., Trenton, N.J. |
| REGIONAL VICINITY MAP      | USGS Quadrangle - Newton West, New Jersey  |
| CONSTRUCTION HISTORY       | Available - Files of NJDEP, Bur. Flood Plain Management                                      |
| TYPICAL SECTIONS OF DAM    | " " " " " "  |
| HYDROLOGIC/HYDRAULIC DATA  | " " " " " "  |
| OUTLETS - PLAN             | " " " " " "  |
| - DETAILS                  | " " " " " "  |
| -CONSTRAINTS               | Not Available  |
| -DISCHARGE RATINGS         | Not Available  |
| RAINFALL/RESERVOIR RECORDS | Not Available  |

| ITEM | REMARKS |
|------|---------|
|------|---------|

SPILLWAY PLAN Available - Files NJDEP - Bureau Flood Plain Management

SECTIONS " " " " " " " "

DETAILS " " " " " " " "

OPERATING EQUIPMENT  
PLANS & DETAILS Not Available

| ITEM                             | REMARKS       |
|----------------------------------|---------------|
| DESIGN REPORTS                   | Not Available |
| GEOLOGY REPORTS                  | Not Available |
| DESIGN COMPUTATIONS              | Not Available |
| HYDROLOGY & HYDRAULICS           | Not Available |
| DAM STABILITY                    | Not Available |
| SEEPAGE STUDIES                  | Not Available |
| MATERIALS INVESTIGATIONS         | Not Available |
| BORING RECORDS                   | Not Available |
| LABORATORY                       | Not Available |
| FIELD                            | Not Available |
| POST-CONSTRUCTION SURVEYS OF DAM | Not Available |
| BORROW SOURCES                   | Not Available |



| ITEM  | REMARKS        |
|---|----------------|
| MONITORING SYSTEMS  | None available |
| MODIFICATIONS   | None Available |
| HIGH POOL RECORDS   | None Available |
| POST CONSTRUCTION ENGINEERING<br>STUDIES AND REPORTS        | None Available |
| PRIOR ACCIDENTS OR FAILURE OF DAM<br>DESCRIPTION<br>REPORTS | None Available |
| MAINTENANCE<br>OPERATION<br>RECORDS                         | None Available |



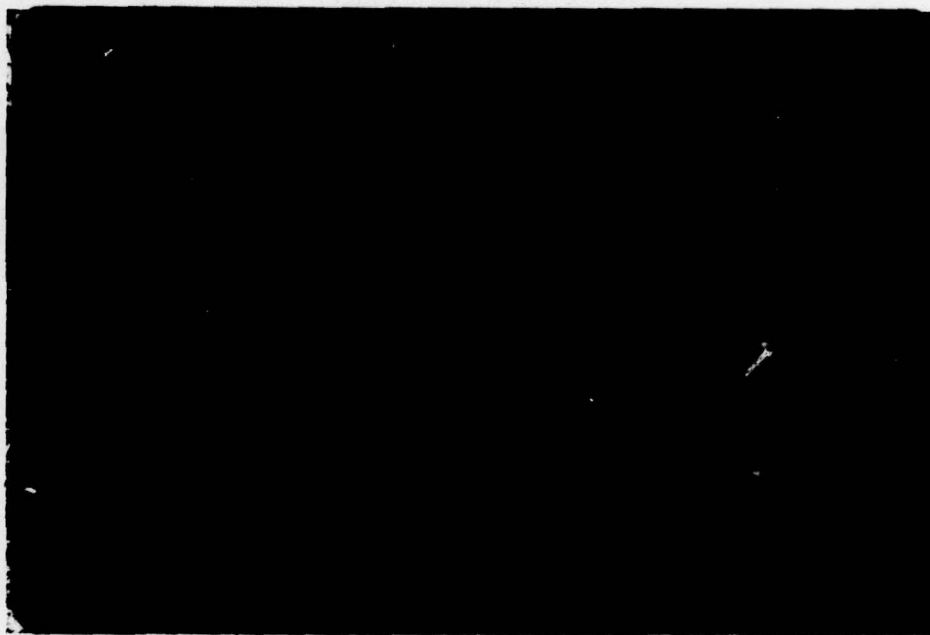
View of Intake Structure

April, 1979



View of Outlet Structure

April, 1979



View Looking Upstream

April, 1979



View of Auxiliary Spillway

April, 1979



CHECK LIST  
HYDROLOGIC AND HYDRAULIC DATA  
ENGINEERING DATA

DRAINAGE AREA CHARACTERISTICS: 7.45

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): 762.9 MSL (168 acre-feet)

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): N/A

ELEVATION MAXIMUM DESIGN POOL: 764.3 MSL

ELEVATION TOP DAM: 767.9 MSL

CREST: \_\_\_\_\_

- a. Elevation 764.3
- b. Type Auxiliary spillway channel w/concrete control section
- c. Width 80-feet wide channel at crest
- d. Length 280 feet long channel
- e. Location Spillover left abutment
- f. Number and Type of Gates None

OUTLET WORKS: Principal spillway (crest El. 762.9)

- a. Type Drop inlet with 6' diameter C.M. discharge pipe
- b. Location 132 feet from right abutment
- c. Entrance inverts 751.5 MSL
- d. Exit inverts 751.0 MSL
- e. Emergency draindown facilities Gate at invert El. 751.6

HYDROMETEOROLOGICAL GAGES: \_\_\_\_\_

- a. Type None
- b. Location \_\_\_\_\_
- c. Records \_\_\_\_\_

MAXIMUM NON-DAMAGING DISCHARGE: 5113 cfs

BY D. J. M. DATE 5-79

LOUIS BERGER &amp; ASSOCIATES INC.

SHEET NO. A1 OF ...CHKD. BY ... DATE ...WILLOW CREST LAKE DAMPROJECT C234SUBJECT ...Time of concentration:

Length of longest watercourse = 3.3 miles = 17,424'

 $\Delta H \approx 210'$ 

$$\therefore \text{Slope} = \frac{210}{17,424} = 1.2\%$$

Assume for this slope velocity = 3 ft. s<sup>-1</sup>

$$\therefore t_c = \frac{17,424}{3 \times 3600} = 1.61 \text{ hours} \quad (\text{overland flow negligible})$$

By California Culverts formula:

$$t_c = \left( \frac{11.9 L^3}{H} \right)^{0.385} = \left( \frac{11.9 \times 3.3^3}{210} \right)^{0.385}$$
$$= 1.31 \text{ hours}$$

By Kirpich's formula:

$$t_c = \frac{0.00013 \times 17424^{0.77}}{0.012^{0.385}}$$
$$= 1.32 \text{ hours}$$

Use  $t_c = 1.5$  hours. and use 1/4 hour increments

BY D. J. M. DATE 5-79

LOUIS BERGER &amp; ASSOCIATES INC.

SHEET NO. A2 OF

CHKD. BY \_\_\_\_\_ DATE \_\_\_\_\_

WILLOW CREST LAKE DAMPROJECT C-234

SUBJECT \_\_\_\_\_

$$t_p = \frac{0.25}{2} + 0.6 \times 1.5 = 1.03 \text{ hours}$$

$$Q_p = \frac{484 \times 7.45}{1.03} = 3518$$

Unitgraph :

| <u>T</u><br><u>hours</u> | <u>T/T<sub>p</sub></u> | <u>Dimensionless</u><br><u>Ordinate (D<sub>0</sub>)</u> | <u>Q (cfs)</u><br><u>= Q<sub>p</sub> × D<sub>0</sub></u> |
|--------------------------|------------------------|---|--|
| 0.25                     | 0.24                   | 0.10  | 352  |
| 0.50                     | 0.49                   | 0.41  | 1442   |
| 0.75                     | 0.73                   | 0.81  | 2850   |
| 1.00                     | 0.97                   | 0.997   | 3507   |
| 1.25                     | 1.21                   | 0.91  | 3201   |
| 1.50                     | 1.46                   | 0.697   | 2452   |
| 1.75                     | 1.70                   | 0.48  | 1689   |
| 2.00                     | 1.94                   | 0.348   | 1224   |
| 2.25                     | 2.18                   | 0.247   | 869  |
| 2.50                     | 2.43                   | 0.171   | 602  |
| 2.75                     | 2.67                   | 0.118   | 415  |
| 3.00                     | 2.91                   | 0.084   | 296  |
| 3.25                     | 3.16                   | 0.059   | 208  |
| 3.50                     | 3.40                   | 0.042   | 148  |
| 3.75                     | 3.64                   | 0.030   | 106  |
| 4.00                     | 3.88                   | 0.022   | 77   |



BY D. J. M. DATE 5-79

LOUIS BERGER &amp; ASSOCIATES INC.

SHEET NO. A3 OF

CHKD. BY \_\_\_\_\_ DATE \_\_\_\_\_

N. J. NORTH DAM INSPECTIONSPROJECT C234SUBJECT RAINFALL DATA FROM T.P. 40 & NOAA TECH. MEMO. NWS HYDRO 35

100 YEAR FREQUENCY EVENT :

(See depth duration curve overleaf)

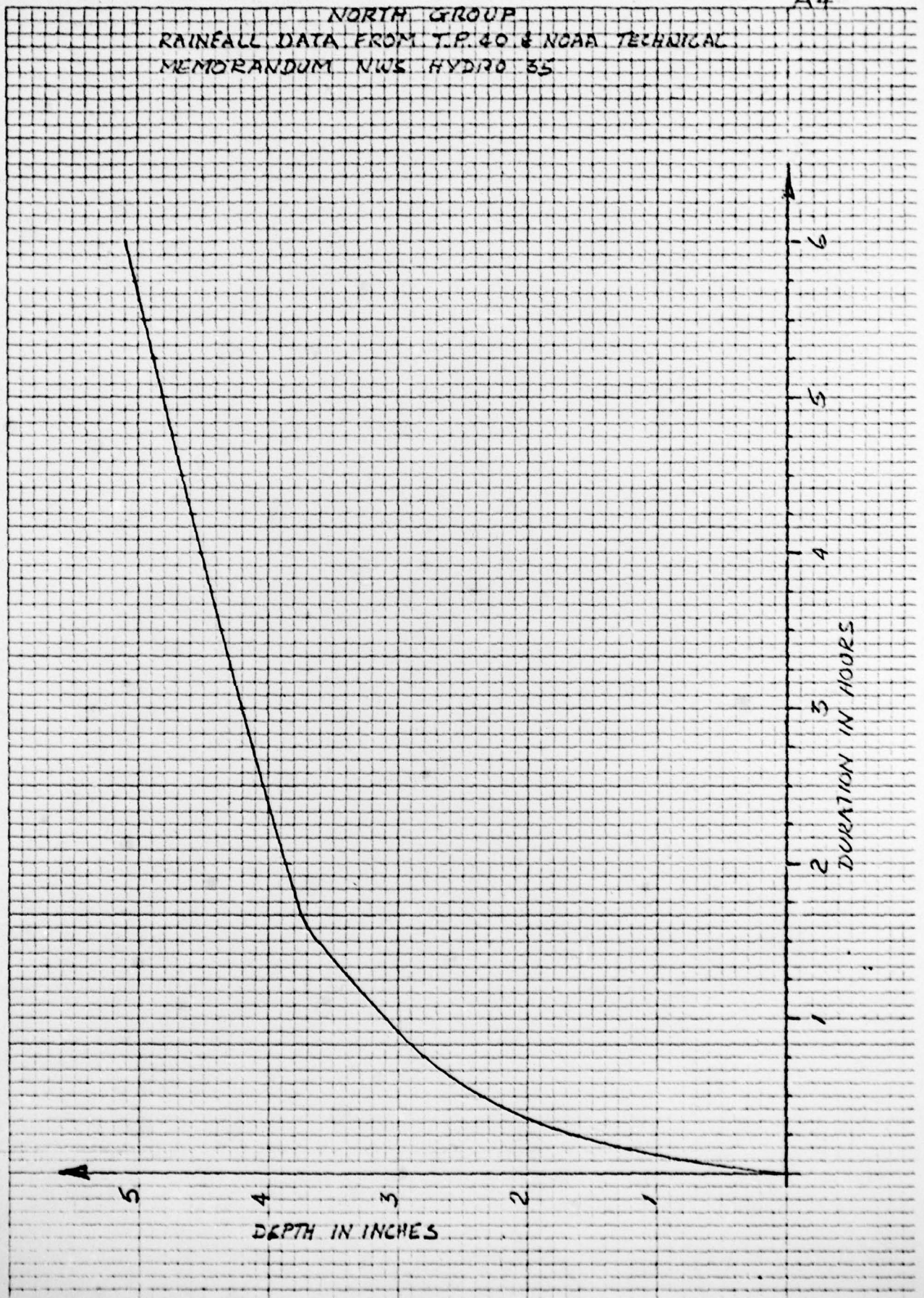
| <u>Time</u><br><u>(hrs)</u> | <u>Precipitation</u><br><u>(inches)</u> | <u><math>\Delta</math></u><br><u>(inches)</u> | <u>Rearrange <math>\Delta</math></u><br><u>(inches)</u> |
|-----------------------------|---|---|---|
| 0.25                        | 1.65                                    | 1.65  | 0.07  |
| 0.50                        | 2.36                                    | 0.71  | 0.07  |
| 0.75                        | 2.80                                    | 0.44  | 0.08  |
| 1.00                        | 3.10                                    | 0.30  | 0.08  |
| 1.25                        | 3.37                                    | 0.27  | 0.08  |
| 1.50                        | 3.61                                    | 0.24  | 0.08  |
| 1.75                        | 3.78                                    | 0.17  | 0.08  |
| 2.00                        | 3.87                                    | 0.09  | 0.09  |
| 2.25                        | 3.96                                    | 0.09  | 0.24  |
| 2.50                        | 4.04                                    | 0.08  | 0.30  |
| 2.75                        | 4.12                                    | 0.08  | 0.71  |
| 3.00                        | 4.20                                    | 0.08  | 1.65  |
| 3.25                        | 4.28                                    | 0.08  | 0.44  |
| 3.50                        | 4.36                                    | 0.08  | 0.27  |
| 3.75                        | 4.44                                    | 0.08  | 0.17  |
| 4.00                        | 4.52                                    | 0.08  | 0.09  |
| 4.25                        | 4.60                                    | 0.08  | 0.08  |
| 4.50                        | 4.68                                    | 0.08  | 0.08  |
| 4.75                        | 4.76                                    | 0.07  | 0.08  |
| 5.00                        | 4.82                                    | 0.07  | 0.08  |
| 5.25                        | 4.89                                    | 0.07  | 0.07  |
| 5.50                        | 4.96                                    | 0.07  | 0.07  |
| 5.75                        | 5.03                                    | 0.07  | 0.07  |
| 6.00                        | 5.10                                    | 0.07  | 0.07  |

K&E 10 X 10 TO THE INCH 5.7 X 10 INCHES  
HEUFFEL & ESSER CO. MADE IN U.S.A.

46 0706

NORTH GROUP  
RAINFALL DATA FROM T.P. 40 & NOAA TECHNICAL  
MEMORANDUM NWS HYDRO 35

A4





BY D. J. M. DATE 6-79

LOUIS BERGER &amp; ASSOCIATES INC.

SHEET NO. A4a OF

CHKD. BY DATE

WILLOW CREST LAKE DAM

PROJECT C 234

SUBJECT Spillway discharge calculations

## Spillway discharge:

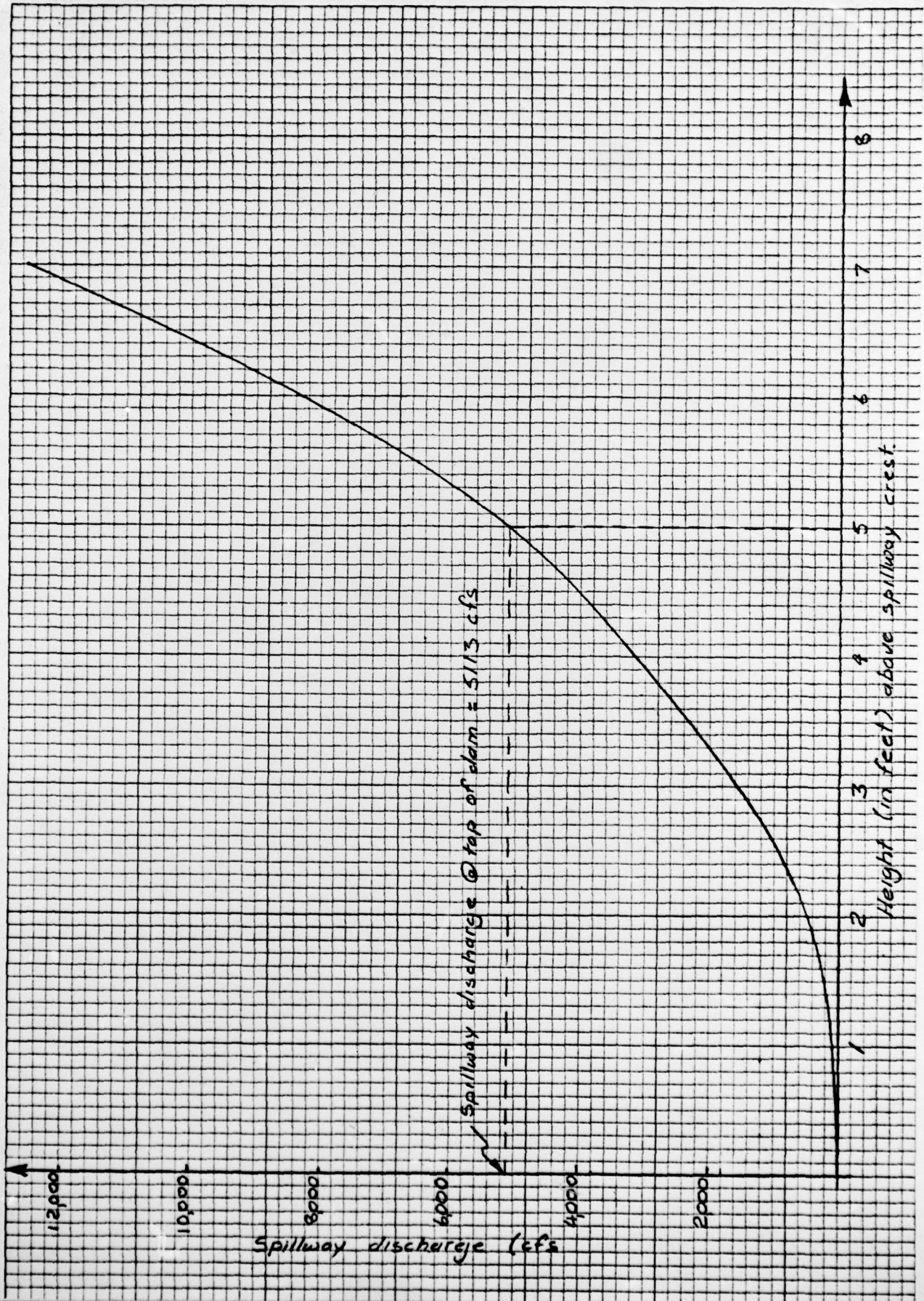
| flow over riser<br>effective $L = 25'$ |   |     |    | Culvert flow<br>$a = 37.5 \text{ ft}^2$<br>$C = .6$ |     | flow through<br>pipe |     | Controlling<br>$Q$ |
|--|---|-----|----|---|-----|----------------------|-----|--------------------|
| El.                                    | H | C   | Q  | H   | Q   | H                    | Q   | Q                  |
| 762.9                                  | 0 |     |    |   |     | 5.3                  | 353 | 0                  |
| 763.9                                  | 1 | 3.2 | 80 |   |     | 6.3                  | 385 | 80                 |
| 764.9                                  |   |     |    | 2   | 255 | 7.3                  | 414 | 255                |
| 765.9                                  |   |     |    | 3   | 313 | 8.3                  | 442 | 313                |
| 766.9                                  |   |     |    | 4   | 361 | 9.3                  | 467 | 361                |
| 767.9                                  |   |     |    | 5   | 403 | 10.3                 | 492 | 403                |
| 768.4                                  |   |     |    | 5.5   | 423 | 10.8                 | 504 | 423                |
| 768.9                                  |   |     |    | 6   | 442 | 11.3                 | 515 | 442                |
| 769.9                                  |   |     |    | 7   | 477 | 12.3                 | 538 | 477                |
| 770.9                                  |   |     |    | 8   | 510 | 13.3                 | 559 | 510                |

| Over emergency<br>spillway $L = 80'$<br>$n = 0.035$ (Mannings) |     |       | Over dam<br>$L = 320$ |     |      | $\Sigma Q$ |
|--|-----|-------|-----------------------|-----|------|------------|
| El.  | H   | Q     | H                     | C   | Q    | Q          |
| 762.9  |     |       |                       |     |      | 0          |
| 763.9  |     |       |                       |     |      | 80         |
| 764.9  | 0.6 | 249   |                       |     |      | 504        |
| 765.9  | 1.6 | 1258  |                       |     |      | 1571       |
| 766.9  | 2.6 | 2781  |                       |     |      | 3142       |
| 767.9  | 3.6 | 4710  | 0                     |     |      | 5113       |
| 768.4  | 4.1 | 5805  | 0.5                   | 2.8 | 317  | 6545       |
| 768.9  | 4.6 | 6980  | 1.0                   | 2.8 | 896  | 8318       |
| 769.9  | 5.6 | 9546  | 2.0                   | 2.8 | 2534 | 12557      |
| 770.9  | 6.6 | 12372 | 3.0                   | 2.8 | 4656 | 17538      |

for flow through pipe  $Q =$   
 $L = 70'$   $K_e = 0.5$   
 $n = 0.035$   $D = 6'$

$$Q = \sqrt{\frac{100 H_T}{\left( \frac{2.5204(1+K_e)}{D^4} + \frac{466.18 n^2 L}{D^{14/3}} \right)}}$$





BY D.J.M. DATE 5-79

CHKD. BY \_\_\_\_\_ DATE \_\_\_\_\_

SUBJECT \_\_\_\_\_

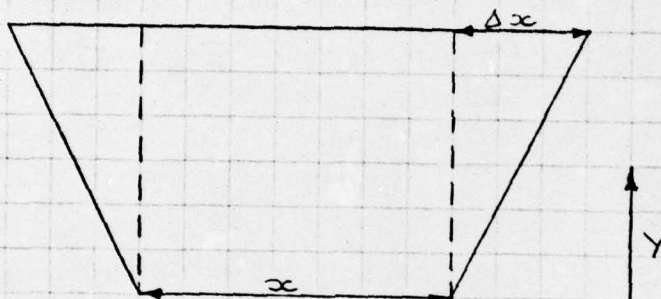
LOUIS BERGER & ASSOCIATES INC.

WILLOW CREST LAKE DAM

SHEET NO. A6 OF \_\_\_\_\_

PROJECT C 234

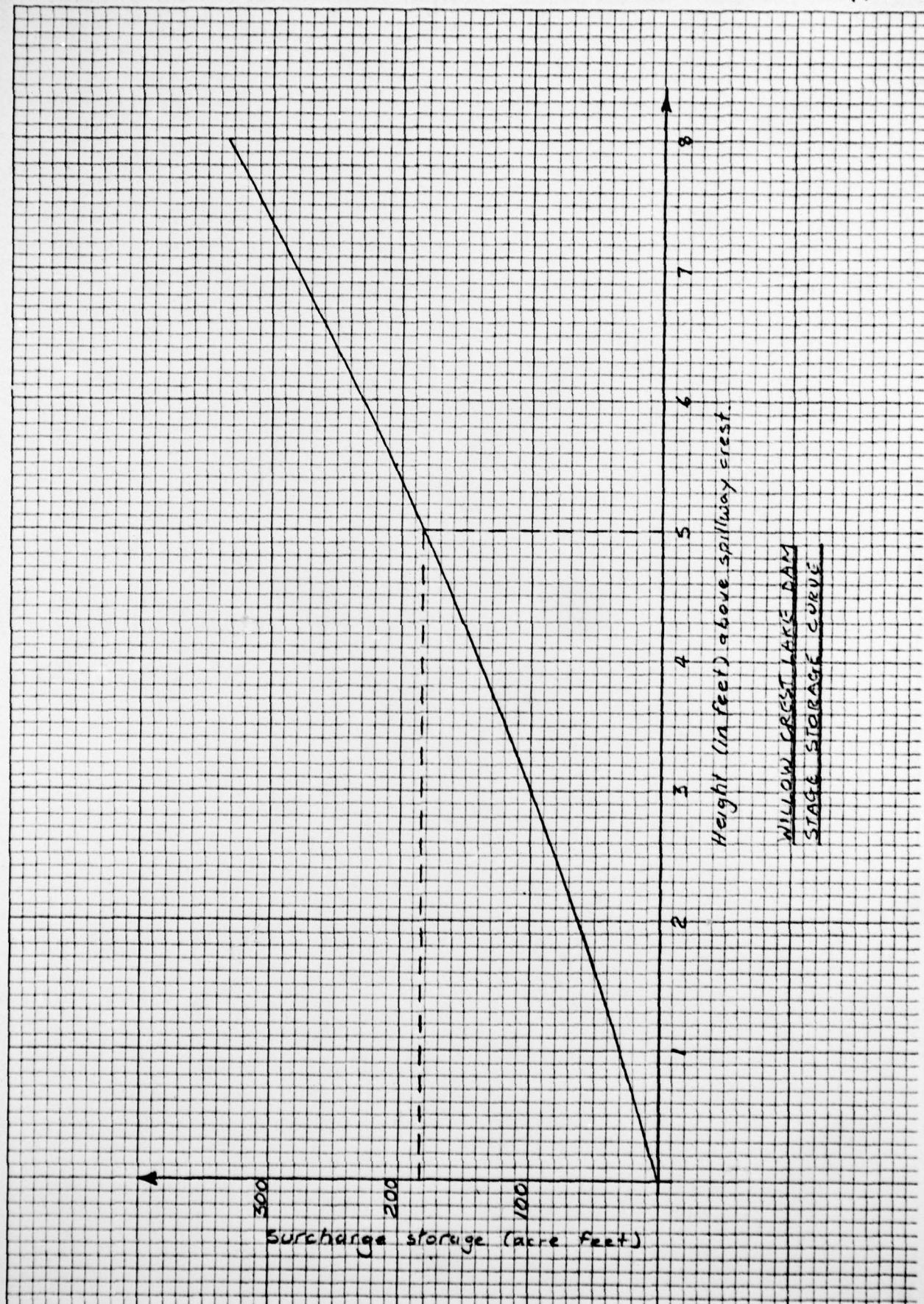
SURCHARGE STORAGE :



Increment in volume  $\Delta V = (x + \Delta x)Y$

| Elevation<br>(M.S.L.) | H<br>(ft) | Surcharge storage<br>(acre feet) |
|-----------------------|-----------|----------------------------------|
| 762.9                 | 0         | 0                                |
| 763.9                 | 1         | 30                               |
| 764.9                 | 2         | 63                               |
| 765.9                 | 3         | 100                              |
| 766.9                 | 4         | 140                              |
| 767.9                 | 5         | 183                              |
| 768.4                 | 5.5       | 206                              |
| 768.9                 | 6         | 230                              |
| 769.9                 | 7         | 281                              |
| 770.9                 | 8         | 334                              |





Height (in feet) above spillway crest.

WILLOW CREST LAKE DAM  
STAGE STORAGE CURVE

Surge storage (acre feet)



BY D. J. M. DATE 6-79

LOUIS BERGER &amp; ASSOCIATES INC.

SHEET NO. A8 OF

CHKD. BY DATE

WILLOW CREST LAKE DAM

PROJECT C-234

SUBJECT Approximate drawdown calculations

Volume @ normal pool = 168 acre feet = 7,318,080 ft<sup>3</sup>

Elevation of top of 24" pipe = 753.6 ± ∴ H = 9.3'

drawdown in 2 stages of: H = 6.98' & H = 2.33'

Assume no tailwater and no inflow.

Stage 1)

$$Q = \pi \times 1^2 \times 0.6 \sqrt{64.32 \times 6.98} = 40 \text{ cfs}$$

$$\text{time : } = \frac{7,318,080}{2 \times 40 \times 3600} = 25.4 \text{ hours}$$

Stage 2)

$$Q = \pi \times 1^2 \times 0.6 \sqrt{64.32 \times 2.33} = 23 \text{ cfs}$$

$$\text{time : } = \frac{7,318,080}{2 \times 23 \times 3600} = 44.2 \text{ hours}$$

$$\text{total drawdown time} = 25.4 + 44.2$$

$$= 69.6 \text{ hours}$$

Say 3 days

BY D. J. M. DATE 6-79

LOUIS BERGER & ASSOCIATES INC.

SHEET NO. A9 OF ...

CHKD. BY ... DATE ...

WILLOW CREST LAKE DAM

PROJECT C234

SUBJECT ...

GENERAL SUMMARY OF APPENDIX :

length of dam = 400'

effective length of spillway = 25' @ El. 762.9

length of auxillary spillway = 80' @ El. 764.3

Total spillway capacity @ top of dam = 5113 cfs

Surcharge storage @ top of dam = 183 acre feet

Storage @ normal pool = 168 acre feet

∴ Total storage @ top of dam = 351 acre feet

Lake area @ normal pool = 28 acres

Lake area @ top of dam = 45 acres

BY LB DATE JUN '79  
 CHKD. BY \_\_\_\_\_ DATE \_\_\_\_\_  
 SUBJECT \_\_\_\_\_

**LOUIS BERGER & ASSOCIATES INC.**  
WILLOW CREST LAKE DAM

SHEET NO. A10 OF \_\_\_\_\_  
 PROJECT C-234

WILLOW CREST LAKE DAM INSPECTION  
 BY LINDA J. BAINES  
 JUNE 14 1979

JOB SPECIFICATION

| NO    | NHR | NMIN | IDAY | IHR | IMIN | METRC | IPLT | IPRT | NSTAN |
|-------|-----|------|------|-----|------|-------|------|------|-------|
| 100   | 0   | 15   | 0    | 0   | 0    | 0     | 0    | 0    | 0     |
| JOPER |     |      |      |     | NWT  |       |      |      |       |
| 3     |     |      |      |     | 0    |       |      |      |       |

SUB-AREA RUNOFF COMPUTATION

INFLOW TO RESERVOIR

| ISTAG | ICOMP | IECCN | ITAPE | JPLT | JPRT | INAME |
|-------|-------|-------|-------|------|------|-------|
| 12    | 0     | 0     | 0     | 0    | 0    | 1     |

HYDROGRAPH DATA

| IHYDG | IUHG | YAREA | SNAP | YRSDA | YKSPC | RATIO | ISNOW | ISAME | LOCAL |
|-------|------|-------|------|-------|-------|-------|-------|-------|-------|
| 0     | -1   | 7.45  | 0.0  | 7.45  | 0.0   | 0.0   | 0     | 0     | 0     |

PRECIP DATA

| NP | STORM | DAJ | DAK |
|----|-------|-----|-----|
| 24 | 0.0   | 0.0 | 0.0 |

PRECIP PATTERN

|      |      |      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|------|------|
| 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 | 0.24 | 0.30 |
| 0.71 | 1.65 | 0.44 | 0.27 | 0.17 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 |
| 0.07 | 0.07 | 0.07 | 0.07 |      |      |      |      |      |      |

LOSS DATA

| STRKR | DLTKR | RTIOL | ERAIN | STRKS | RTIOK | STRTL | CNSTL | ALSMX | RTIMP |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0.0   | 0.0   | 1.00  | 0.0   | 0.0   | 1.00  | 0.50  | 0.10  | 0.0   | 0.0   |

GIVEN UNIT GRAPH, NUHGC= 16

|      |       |       |       |       |       |       |       |      |      |
|------|-------|-------|-------|-------|-------|-------|-------|------|------|
| 352. | 1442. | 2850. | 3507. | 3201. | 2452. | 1689. | 1224. | 869. | 602. |
| 415. | 296.  | 208.  | 148.  | 106.  | 77.   |       |       |      |      |

UNIT GRAPH TOTALS 19438. CFS OR 1.01 INCHES OVER THE AREA

RECESSION DATA

STRTO= 0.0 GRCSN= 0.0 RTIOR= 1.00

END-OF-PERIOD FLOW

| TIME | RAIN | EXCS | COMP Q |
|------|------|------|--------|
| 1    | 0.07 | 0.00 | 0.     |
| 2    | 0.07 | 0.00 | 0.     |
| 3    | 0.08 | 0.00 | 0.     |
| 4    | 0.08 | 0.00 | 0.     |
| 5    | 0.08 | 0.00 | 0.     |
| 6    | 0.08 | 0.00 | 0.     |
| 7    | 0.08 | 0.03 | 10.    |
| 8    | 0.09 | 0.06 | 63.    |
| 9    | 0.24 | 0.71 | 248.   |



BY L. B. DATE JUN '79

CHKD. BY \_\_\_\_\_ DATE \_\_\_\_\_

SUBJECT \_\_\_\_\_

## LOUIS BERGER &amp; ASSOCIATES INC.

WILLOW CREST LAKE DAMSHEET NO. ALL OF \_\_\_\_\_PROJECT C-234

|    |      |      |        |
|----|------|------|--------|
| 10 | 0.30 | 0.27 | 689.   |
| 11 | 0.71 | 0.68 | 1566.  |
| 12 | 1.65 | 1.62 | 3373.  |
| 13 | 0.44 | 0.41 | 6300.  |
| 14 | 0.27 | 0.24 | 9269.  |
| 15 | 0.17 | 0.14 | 10620. |
| 16 | 0.09 | 0.06 | 10663. |
| 17 | 0.08 | 0.05 | 8429.  |
| 18 | 0.08 | 0.05 | 6581.  |
| 19 | 0.08 | 0.05 | 5113.  |
| 20 | 0.08 | 0.05 | 3554.  |
| 21 | 0.07 | 0.05 | 3087.  |
| 22 | 0.07 | 0.05 | 2466.  |
| 23 | 0.07 | 0.05 | 2023.  |
| 24 | 0.07 | 0.05 | 1691.  |
| 25 | 0.0  | 0.0  | 1430.  |
| 26 | 0.0  | 0.0  | 1189.  |
| 27 | 0.0  | 0.0  | 514.   |
| 28 | 0.0  | 0.0  | 598.   |
| 29 | 0.0  | 0.0  | 408.   |
| 30 | 0.0  | 0.0  | 274.   |
| 31 | 0.0  | 0.0  | 187.   |
| 32 | 0.0  | 0.0  | 128.   |
| 33 | 0.0  | 0.0  | 87.    |
| 34 | 0.0  | 0.0  | 58.    |
| 35 | 0.0  | 0.0  | 38.    |
| 36 | 0.0  | 0.0  | 24.    |
| 37 | 0.0  | 0.0  | 15.    |
| 38 | 0.0  | 0.0  | 8.     |
| 39 | 0.0  | 0.0  | 3.     |
| 40 | 0.0  | 0.0  | 0.     |
| 41 | 0.0  | 0.0  | 0.     |
| 42 | 0.0  | 0.0  | 0.     |
| 43 | 0.0  | 0.0  | 0.     |
| 44 | 0.0  | 0.0  | 0.     |
| 45 | 0.0  | 0.0  | 0.     |
| 46 | 0.0  | 0.0  | 0.     |
| 47 | 0.0  | 0.0  | 0.     |
| 48 | 0.0  | 0.0  | 0.     |
| 49 | 0.0  | 0.0  | 0.     |
| 50 | 0.0  | 0.0  | 0.     |
| 51 | 0.0  | 0.0  | 0.     |
| 52 | 0.0  | 0.0  | 0.     |
| 53 | 0.0  | 0.0  | 0.     |
| 54 | 0.0  | 0.0  | 0.     |
| 55 | 0.0  | 0.0  | 0.     |
| 56 | 0.0  | 0.0  | 0.     |
| 57 | 0.0  | 0.0  | 0.     |
| 58 | 0.0  | 0.0  | 0.     |
| 59 | 0.0  | 0.0  | 0.     |
| 60 | 0.0  | 0.0  | 0.     |
| 61 | 0.0  | 0.0  | 0.     |
| 62 | 0.0  | 0.0  | 0.     |
| 63 | 0.0  | 0.0  | 0.     |
| 64 | 0.0  | 0.0  | 0.     |
| 65 | 0.0  | 0.0  | 0.     |
| 66 | 0.0  | 0.0  | 0.     |
| 67 | 0.0  | 0.0  | 0.     |
| 68 | 0.0  | 0.0  | 0.     |
| 69 | 0.0  | 0.0  | 0.     |
| 70 | 0.0  | 0.0  | 0.     |

BY L.B. DATE JUN '79

CHKD. BY \_\_\_\_\_ DATE \_\_\_\_\_

SUBJECT \_\_\_\_\_

LOUIS BERGER & ASSOCIATES INC.

WILLOW CREST LAKE DAM

SHEET NO. A12 OF \_\_\_\_\_

PROJECT C-234

|     |      |      |        |     |     |
|-----|------|------|--------|-----|-----|
| 71  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 72  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 73  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 74  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 75  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 76  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 77  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 78  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 79  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 80  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 81  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 82  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 83  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 84  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 85  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 86  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 87  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 88  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 89  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 90  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 91  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 92  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 93  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 94  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 95  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 96  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 97  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 98  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 99  | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| 100 | 0.0  | 0.0  | 0.0    | 0.0 | 0.0 |
| SUM | 5.10 | 4.12 | 20511. |     |     |

|        |        |         |         |              |
|--------|--------|---------|---------|--------------|
| PEAK   | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
| 10620. | 3359.  | 843.    | 809.    | 80910.       |
| CFS    | 4.19   | 4.21    | 4.21    | 4.21         |
| INCHES | 1666.  | 1673.   | 1673.   | 1673.        |
| 70-FT  |        |         |         |              |

HYDROGRAPH ROUTING

ROUTING THROUGH RESERVOIR

| ISTAO | ICOMP | IECON | ITYPE | JPLY | JPRY | INAME |
|-------|-------|-------|-------|------|------|-------|
| 12    | 1     | 0     | 0     | 0    | 0    | 1     |

| ROUTING DATA | AVG | IRIS | ISAME |
|--------------|-----|------|-------|
| 0.0          | 0.0 | 1    | 0     |

| NSTPS | MSIDL | LAG | AMSKK | X   | TSK | STORA |
|-------|-------|-----|-------|-----|-----|-------|
| 1     | 0     | 0   | 0.0   | 0.0 | 0.0 | 0.    |

|          |    |     |     |       |       |       |       |       |        |        |
|----------|----|-----|-----|-------|-------|-------|-------|-------|--------|--------|
| STORAGE= | 0. | 30. | 63. | 100.  | 140.  | 183.  | 206.  | 230.  | 241.   | 334.   |
| OUTFLOW  | 0. | 40. | 50. | 1571. | 3142. | 5113. | 6545. | 8318. | 12557. | 17534. |

| TIME | EQP | STOR | AVG IN | EQP OUT |
|------|-----|------|--------|---------|
| 1    | 0.  | 0.   | 0.     | 0.      |
| 2    | 0.  | 0.   | 0.     | 0.      |
| 3    | 0.  | 0.   | 0.     | 0.      |

BY L.B. DATE JUN '79  
CHKD. BY \_\_\_\_\_ DATE \_\_\_\_\_  
SUBJECT \_\_\_\_\_

LOUIS BERGER & ASSOCIATES INC.  
WILLOW CREST LAKE DAM

SHEET NO. A13 OF \_\_\_\_\_  
PROJECT C-234

|    |      |        |        |
|----|------|--------|--------|
| 4  | 0.   | 0.     | 0.     |
| 5  | 0.   | 0.     | 0.     |
| 6  | 0.   | 0.     | 0.     |
| 7  | 0.   | 5.     | 0.     |
| 8  | 1.   | 36.    | 2.     |
| 9  | 4.   | 155.   | 10.    |
| 10 | 13.  | 468.   | 35.    |
| 11 | 35.  | 1127.  | 139.   |
| 12 | 75.  | 2470.  | 859.   |
| 13 | 136. | 4837.  | 2972.  |
| 14 | 201. | 7785.  | 6249.  |
| 15 | 244. | 9944.  | 9491.  |
| 16 | 254. | 10344. | 10279. |
| 17 | 242. | 9248.  | 9327.  |
| 18 | 221. | 7505.  | 7686.  |
| 19 | 199. | 5847.  | 6137.  |
| 20 | 179. | 4533.  | 4923.  |
| 21 | 159. | 3520.  | 4021.  |
| 22 | 142. | 2777.  | 3221.  |
| 23 | 127. | 2245.  | 2649.  |
| 24 | 116. | 1857.  | 2192.  |
| 25 | 107. | 1561.  | 1828.  |
| 26 | 99.  | 1310.  | 1537.  |
| 27 | 91.  | 1051.  | 1314.  |
| 28 | 82.  | 756.   | 1058.  |
| 29 | 73.  | 503.   | 803.   |
| 30 | 66.  | 341.   | 591.   |
| 31 | 60.  | 230.   | 464.   |
| 32 | 54.  | 157.   | 392.   |
| 33 | 49.  | 107.   | 325.   |
| 34 | 44.  | 72.    | 266.   |
| 35 | 41.  | 48.    | 215.   |
| 36 | 37.  | 31.    | 172.   |
| 37 | 34.  | 20.    | 136.   |
| 38 | 32.  | 12.    | 107.   |
| 39 | 30.  | 6.     | 83.    |
| 40 | 29.  | 2.     | 76.    |
| 41 | 27.  | 0.     | 72.    |
| 42 | 26.  | 0.     | 68.    |
| 43 | 24.  | 0.     | 65.    |
| 44 | 23.  | 0.     | 61.    |
| 45 | 22.  | 0.     | 58.    |
| 46 | 21.  | 0.     | 55.    |
| 47 | 19.  | 0.     | 52.    |
| 48 | 18.  | 0.     | 49.    |
| 49 | 17.  | 0.     | 47.    |
| 50 | 17.  | 0.     | 44.    |
| 51 | 16.  | 0.     | 42.    |
| 52 | 15.  | 0.     | 39.    |
| 53 | 14.  | 0.     | 37.    |
| 54 | 13.  | 0.     | 35.    |
| 55 | 13.  | 0.     | 33.    |
| 56 | 12.  | 0.     | 32.    |
| 57 | 11.  | 0.     | 30.    |
| 58 | 11.  | 0.     | 28.    |
| 59 | 10.  | 0.     | 27.    |
| 60 | 10.  | 0.     | 25.    |
| 61 | 9.   | 0.     | 24.    |
| 62 | 9.   | 0.     | 23.    |
| 63 | 8.   | 0.     | 22.    |
| 64 | 8.   | 0.     | 20.    |



BY LB. DATE JUN '79

LOUIS BERGER &amp; ASSOCIATES INC.

SHEET NO. A14 OF

CHKD. BY DATE

WILLOW CREST LAKE DAMPROJECT C-234

SUBJECT

|        |        |         |         |              |
|--------|--------|---------|---------|--------------|
| 65     | 7.     | 0.      | 19.     |              |
| 66     | 7.     | 0.      | 18.     |              |
| 67     | 6.     | 0.      | 17.     |              |
| 68     | 6.     | 0.      | 16.     |              |
| 69     | 6.     | 0.      | 15.     |              |
| 70     | 5.     | 0.      | 15.     |              |
| 71     | 5.     | 0.      | 14.     |              |
| 72     | 5.     | 0.      | 13.     |              |
| 73     | 5.     | 0.      | 12.     |              |
| 74     | 4.     | 0.      | 12.     |              |
| 75     | 4.     | 0.      | 11.     |              |
| 76     | 4.     | 0.      | 11.     |              |
| 77     | 4.     | 0.      | 10.     |              |
| 78     | 4.     | 0.      | 9.      |              |
| 79     | 3.     | 0.      | 9.      |              |
| 80     | 3.     | 0.      | 8.      |              |
| 81     | 3.     | 0.      | 8.      |              |
| 82     | 3.     | 0.      | 8.      |              |
| 83     | 3.     | 0.      | 7.      |              |
| 84     | 3.     | 0.      | 7.      |              |
| 85     | 2.     | 0.      | 6.      |              |
| 86     | 2.     | 0.      | 6.      |              |
| 87     | 2.     | 0.      | 6.      |              |
| 88     | 2.     | 0.      | 5.      |              |
| 89     | 2.     | 0.      | 5.      |              |
| 90     | 2.     | 0.      | 5.      |              |
| 91     | 2.     | 0.      | 5.      |              |
| 92     | 2.     | 0.      | 4.      |              |
| 93     | 2.     | 0.      | 4.      |              |
| 94     | 1.     | 0.      | 4.      |              |
| 95     | 1.     | 0.      | 4.      |              |
| 96     | 1.     | 0.      | 3.      |              |
| 97     | 1.     | 0.      | 3.      |              |
| 98     | 1.     | 0.      | 3.      |              |
| 99     | 1.     | 0.      | 3.      |              |
| 100    | 1.     | 0.      | 3.      |              |
| SUM    |        | 80858.  |         |              |
| PEAK   | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
| 10279. | 3283.  | 842.    | 809.    | 80858.       |
| INCHES | 4.10   | 4.21    | 4.21    | 4.21         |
| AC-FT  | 1629.  | 1671.   | 1671.   | 1671.        |

## RUNOFF SUMMARY, AVERAGE FLOW

|               |    |        |        |         |         |      |
|---------------|----|--------|--------|---------|---------|------|
|               |    | PEAK   | 6-HOUR | 24-HOUR | 72-HOUR | AREA |
| HYDROGRAPH AT | 12 | 10620. | 3359.  | 843.    | 809.    | 7.45 |
| ROUTED TO     | 12 | 10279. | 3283.  | 842.    | 809.    | 7.45 |